



VIBRATION MEASUREMENT SYSTEM DEVELOPED FOR THE NEW CERN VACUUM WIRE SCANNER

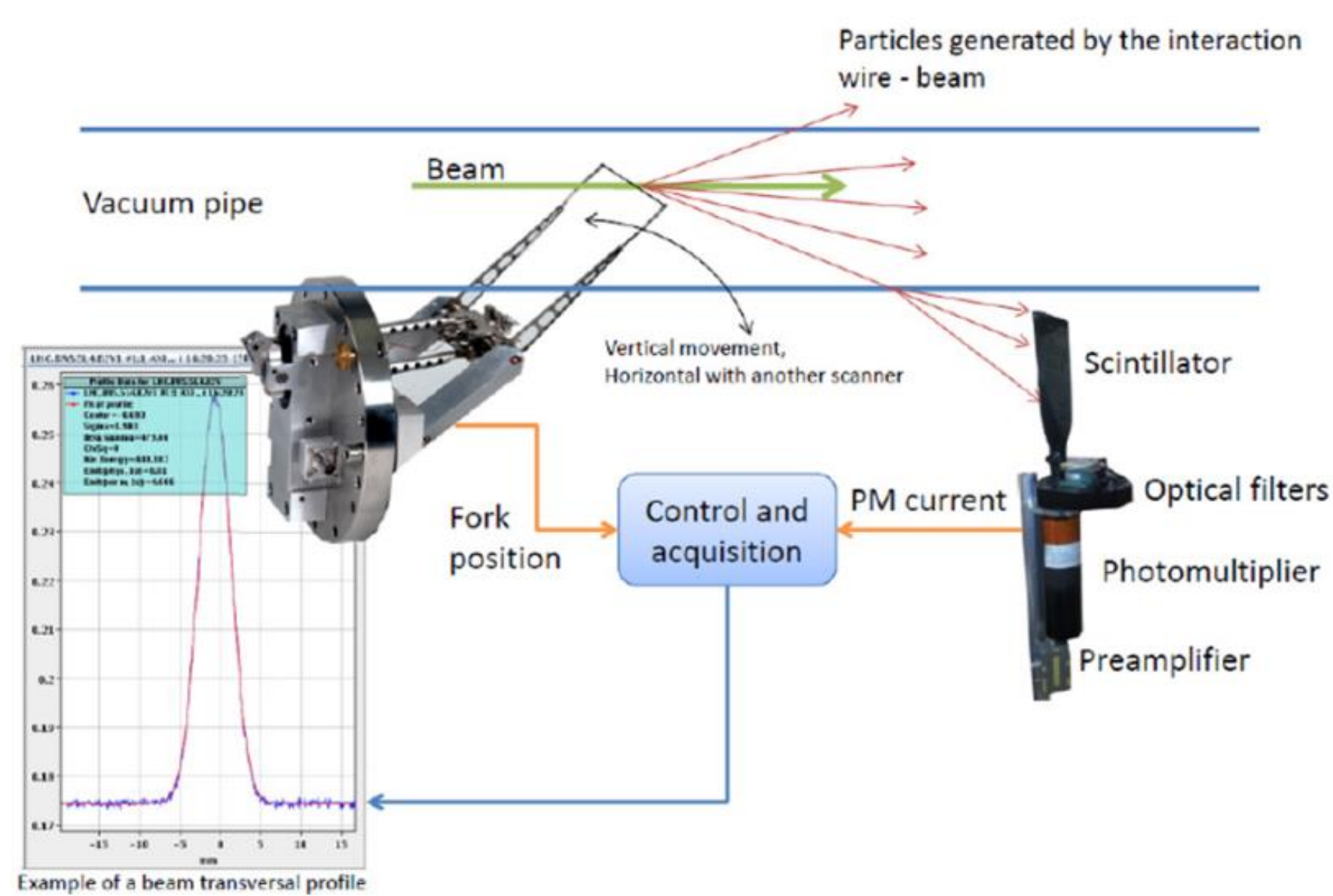
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Abstract: In the next years the luminosity of the LHC will be significantly increased. Therefore a much higher accuracy of beam profile measurement than actually achievable by the current wire scanner is required. The new performance demands a wire travelling speed up to 20 m.s^{-1} and a position measurement accuracy of the order of $1 \mu\text{m}$. The vibrations of the mechanical parts of the system, and mainly the vibrations of the thin carbon wire have been identified as the major error sources contributing to the wire position uncertainty. Therefore the understanding of the wire vibrations has been given high priority for the design and operation of the new device. The most challenging and innovative development has been the measurement of the wire vibrations based on the **piezoresistive** effect of the wire itself. An electronic readout system based on a Wheatstone bridge is used to measure the variation of the carbon wire resistance, which is directly proportional to the wire elongation caused by the oscillations. The deformation of the wire support during the movement (measured through **semiconductor strain gauges** installed on the mechanical parts of the system) and the angular information of the fork (given by a resolver) will be used as inputs of the **dynamic model** of the wire. The final parameters of the dynamic models will be tuned through the comparison of the simulated vibration amplitudes and the wire resistance variation measurements.

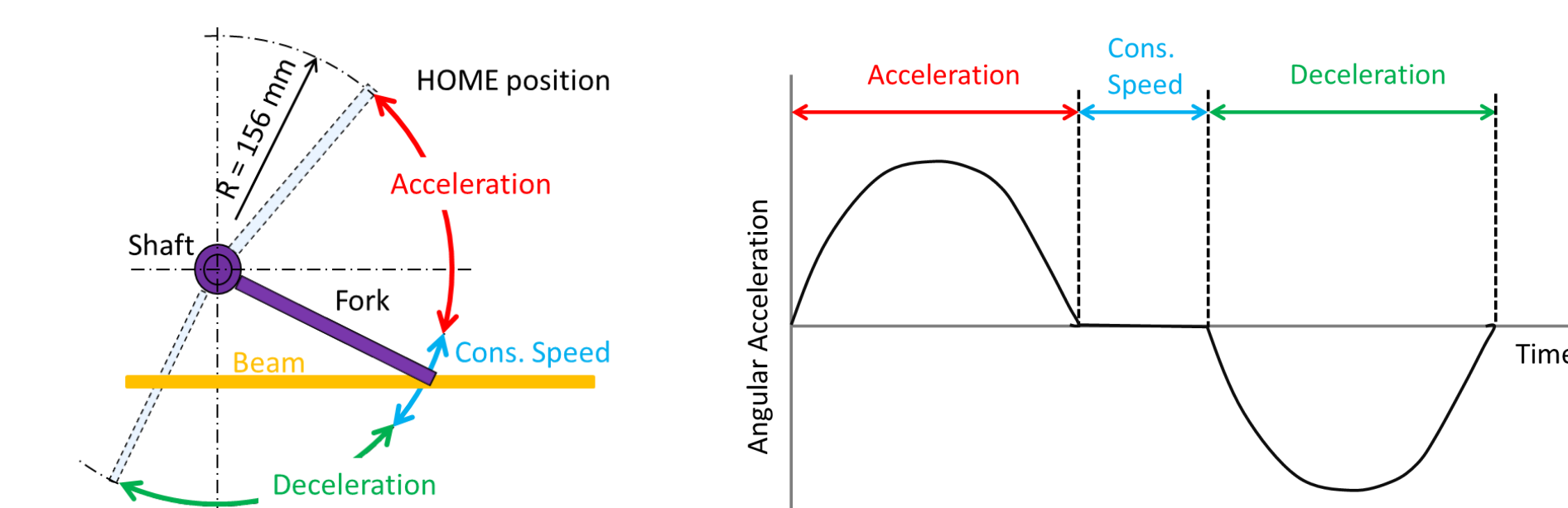
Motivation

Rotating Wire scanner



In order to reconstruct the beam transversal profile, the position of the fork is combined with the photomultiplier signal. Therefore profile accuracy depends on the wire and fork position accuracy determination.

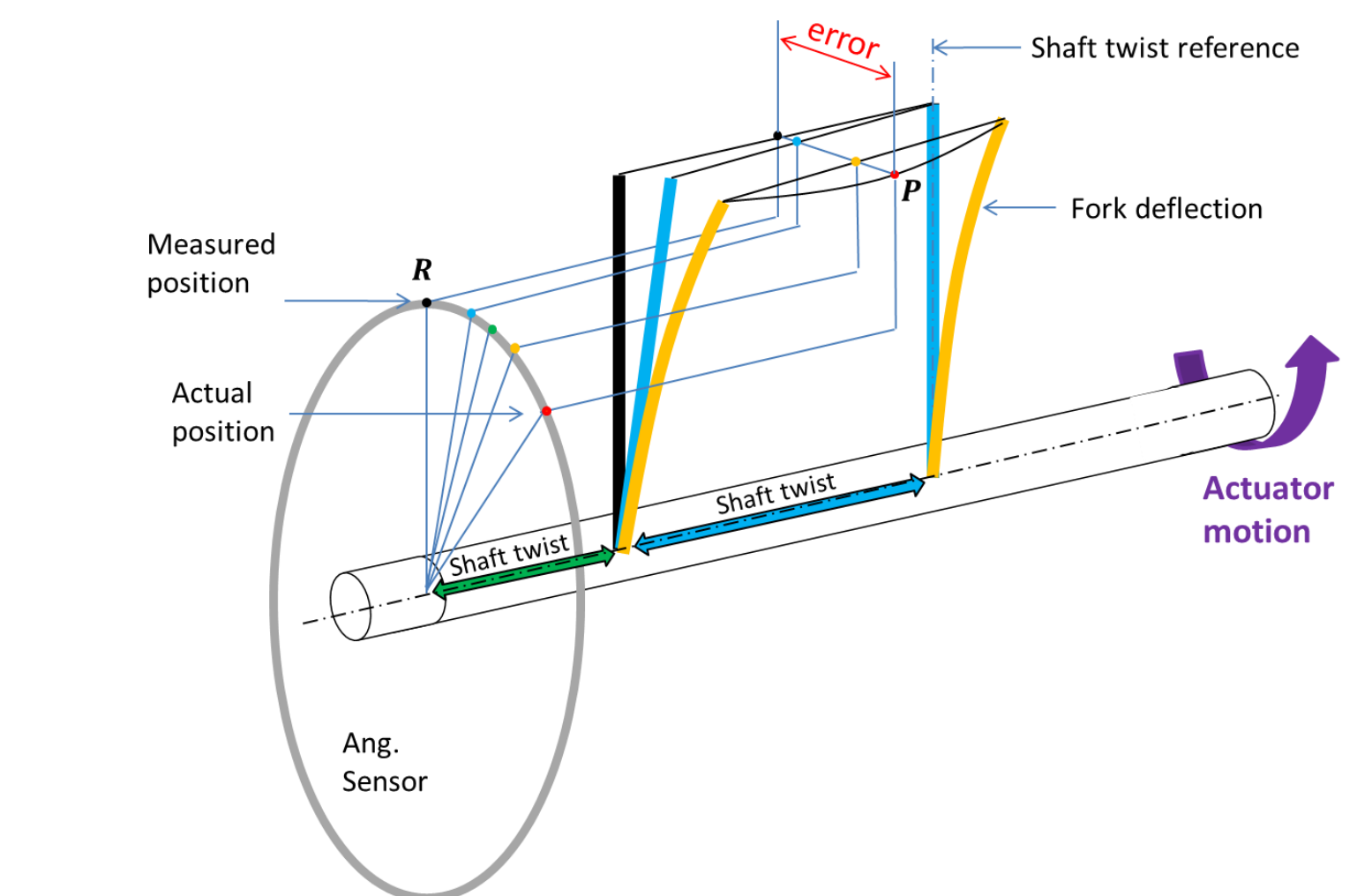
Scan cycle



The typical scan cycle of a rotating wire scanner consists of an angular rotation motion showing an acceleration phase, a constant speed phase and a deceleration phase. Depending on the peak speed required, the length of the fork, the angular travel and the motion pattern design, the pick acceleration values can vary. Typical values for the new CERN vacuum wire scanner are:

Peak speed	20 m/s	Peak angular speed	128.20 rad/s
Fork length	156 mm	Peak angular acceleration	6700 - 10000 rad/s ²
		Tangential acceleration	95 – 159 g
		Normal acceleration	260 g

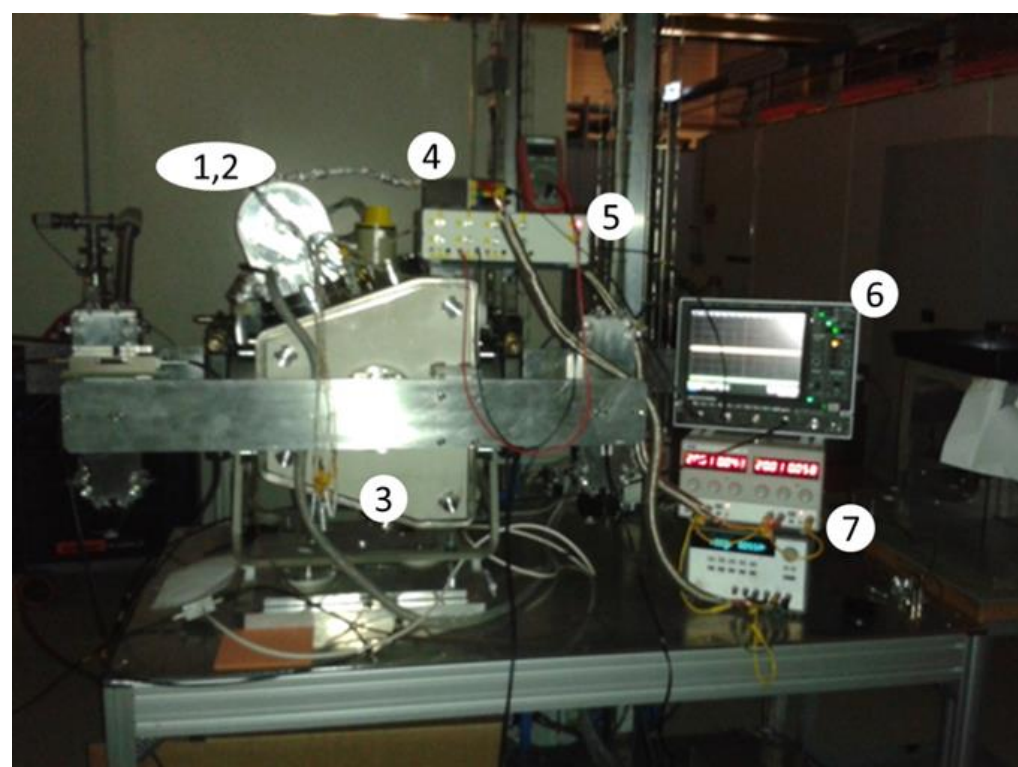
Deflections



The acceleration induces deflections on the measurement chain (shaft, fork and wire) that provoke an error between the real position of the wire midpoint (P) and the position measured by the angular sensor (point R). In addition due to the variations of acceleration these deflections become in oscillations, thus increasing the uncertainty for the wire position determination. For the new CERN vacuum wire scanner the position accuracy requirement is in the range of $1 \mu\text{m}$.

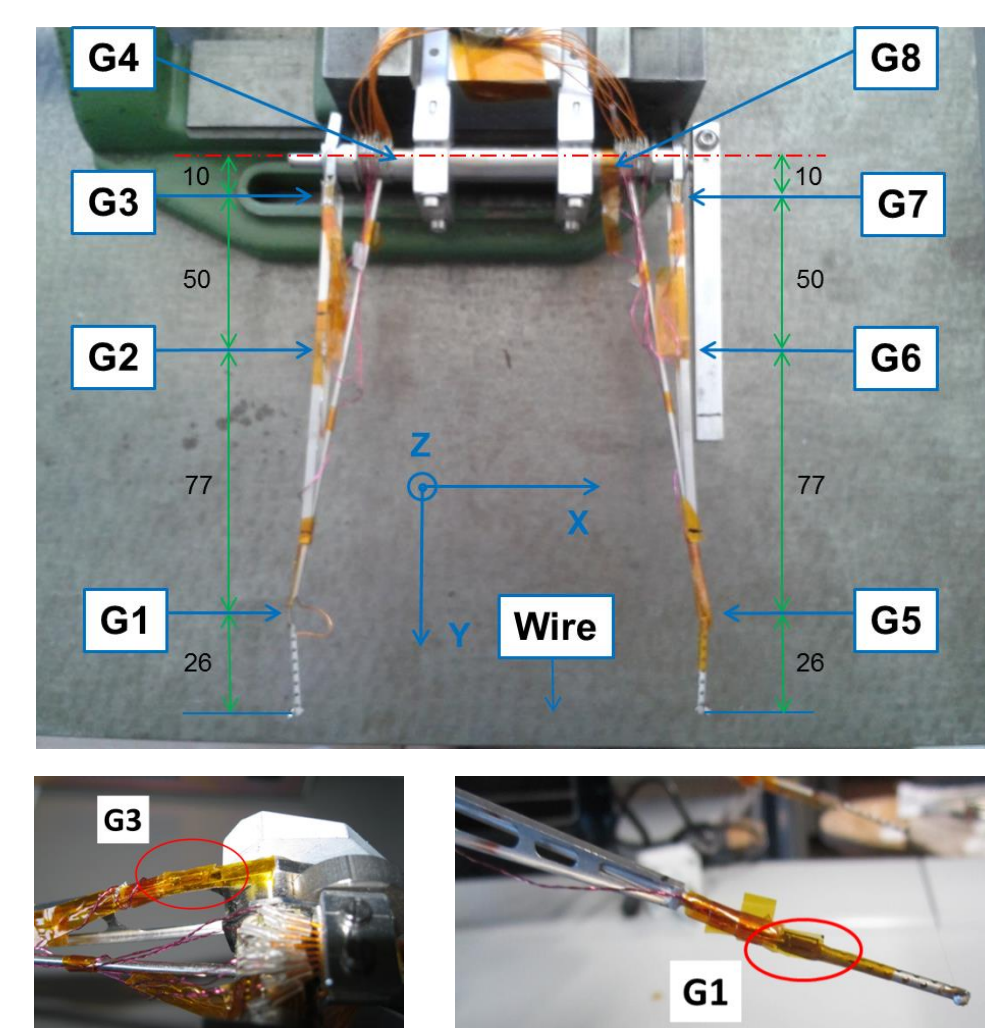
Experimental setup

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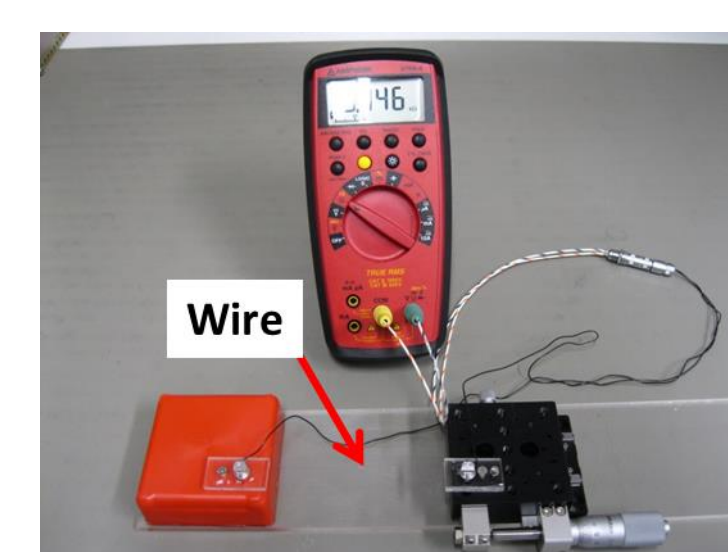
(1) and (2) wire scanner actuator and fork (not shown), (3) vacuum tank, (4) Wheatstone bridge and amplifier for wire, (5) Wheatstone bridge and amplifier for strain gauges, (6) oscilloscope, (7) power supplies.

Strain gauges location



The fork has been equipped with semiconductor strain gauges. Gauges G4 and G8 are mainly sensitive to the twist of the shaft. Gauges G2, G3, G6 and G7 are sensitive to the deflections in Z direction (transversal deflections). Gauges G1 and G5 are mainly sensitive to the deflections in X direction (longitudinal deflections).

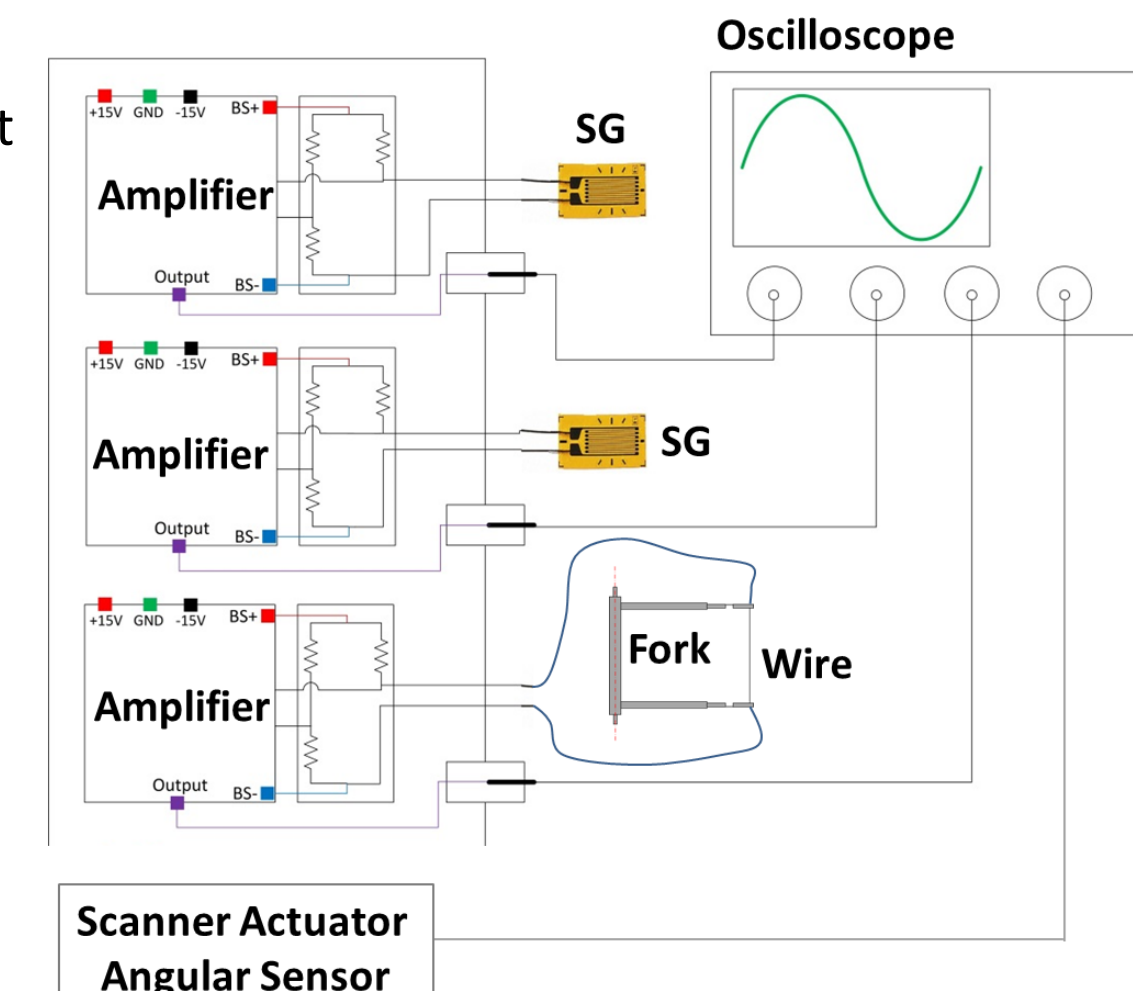
Wire piezoresistive effect



Experimental measurements show that in the standard carbon wire used in CERN's operating wire scanners, a variation of resistance appears under wire elongation.

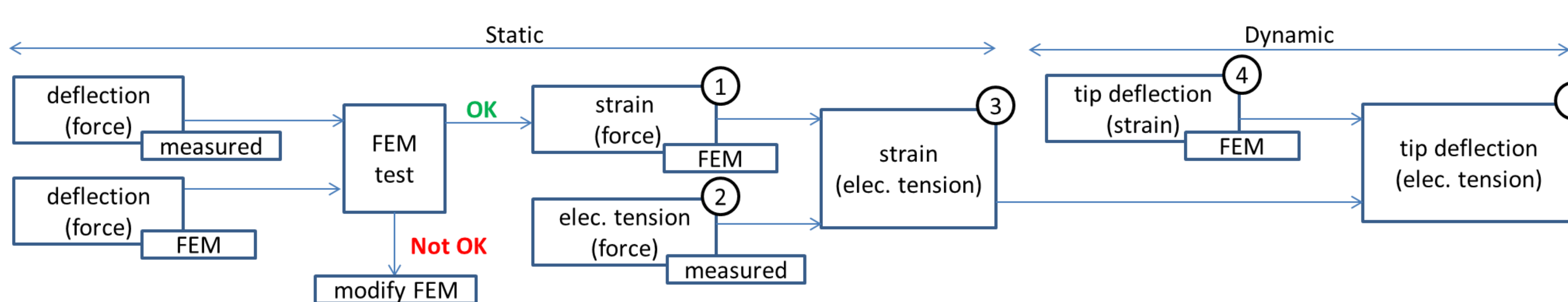
Wire length [mm]	114
Resistance [Ohm/mm]	31
Elongation factor [mm/V]	-0.35
Gauge factor	0.64

Acquisition system



The acquisition systems for the strain gauges and the wire are based in a Wheatstone bridge combined with an amplifier. The amplified tension is read by the a oscilloscope. The acquisition system records also the angular position of the fork by means of an angular sensor.

Calibration

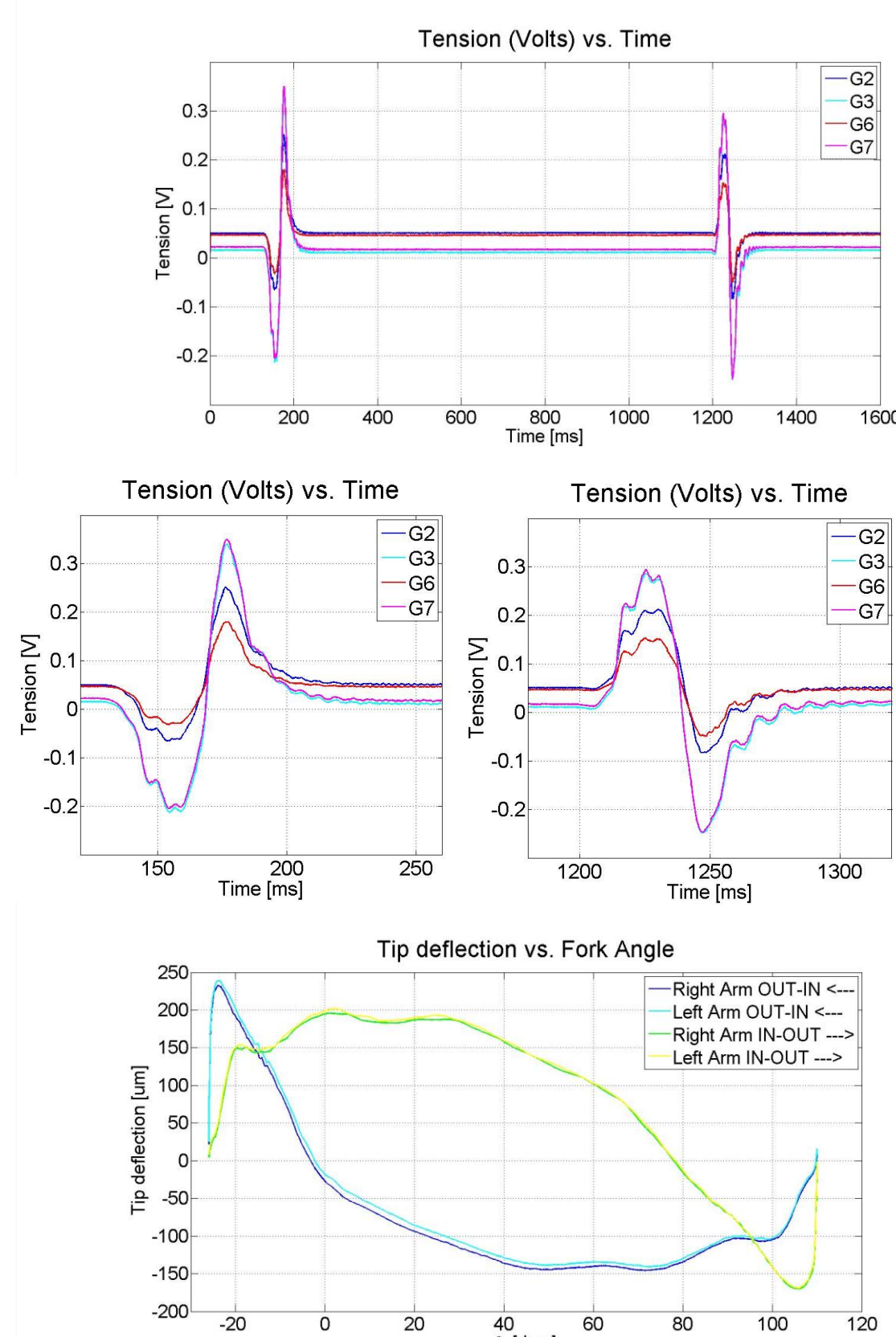


Correlating (strain/force) values from a static FEM of the fork (1) and (elec. tension/force) from the measurements (2), a ratio (strain/elec. tension) for each gauge can be determined (3). From the same FEM, under dynamic forces, the ratio (tip transversal deflection/strain) for different values of angular acceleration has been determined (4). By means of the correlation between the last two correlations, a ratio (tip deflection/elec. tension) is determined (5).

Gauge	Tip trans. def./Tension [mm/mV]
G2	-0.00139
G3	-0.00068
G6	-0.00558
G7	-0.00068

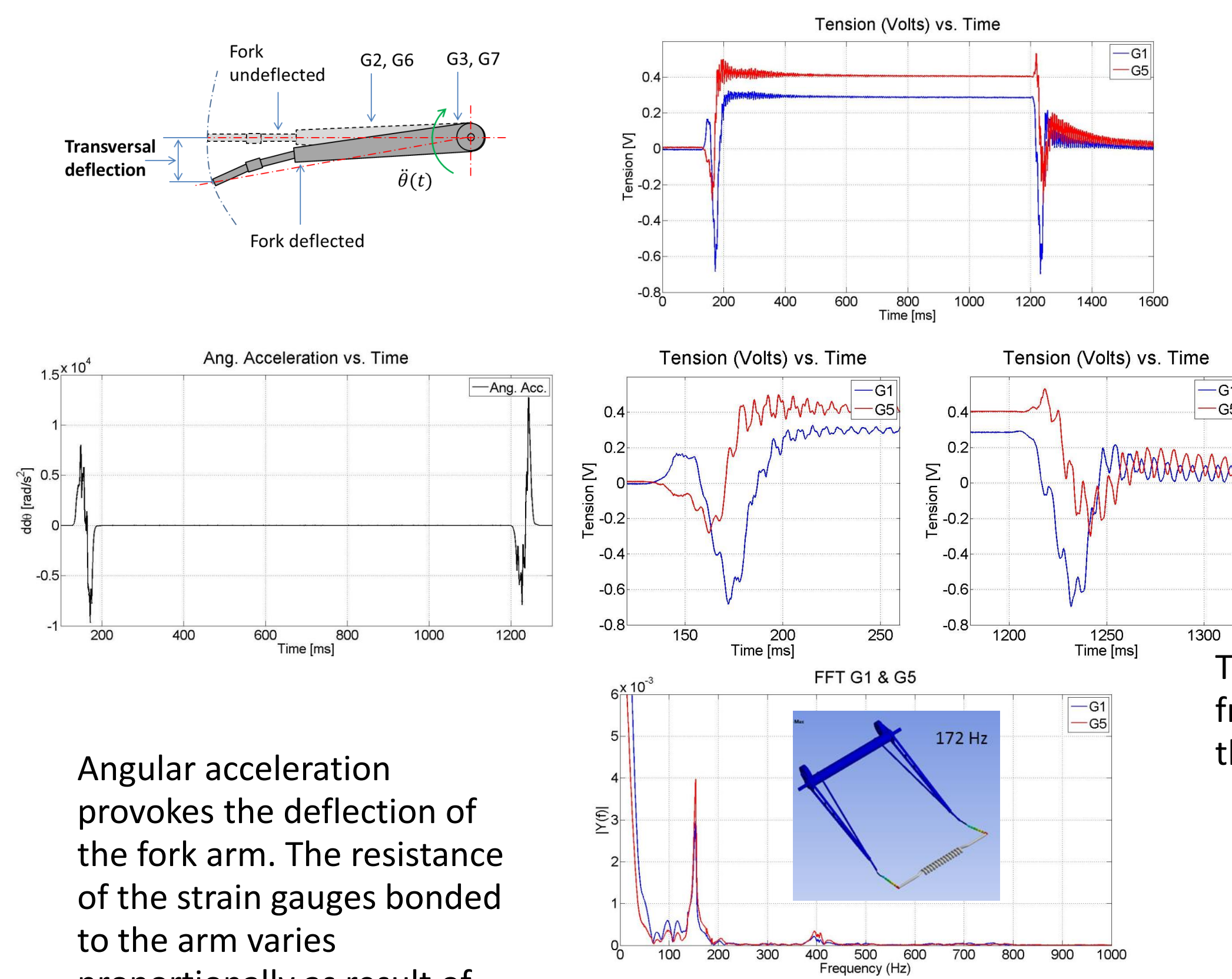
Deflection and Vibrations Measurements

Transversal deflections



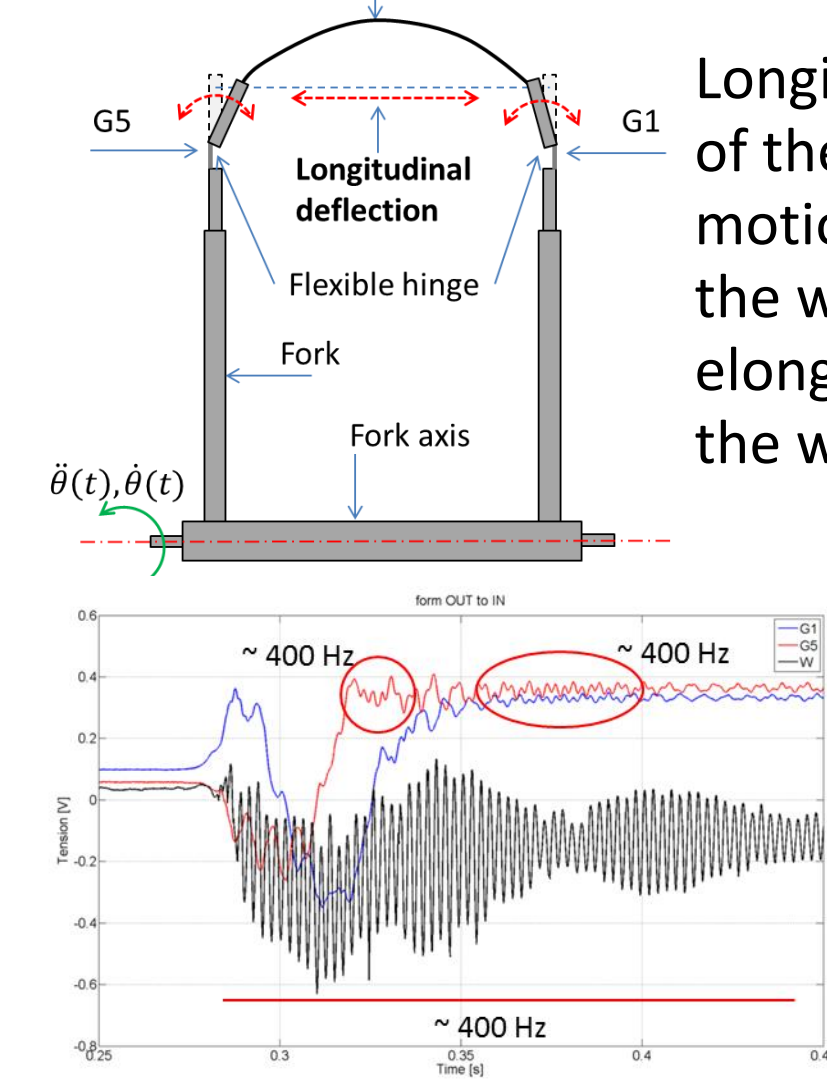
The transversal deflections on the fork tip can be estimated applying experimental calibration factors.

Longitudinal deflections, gauges

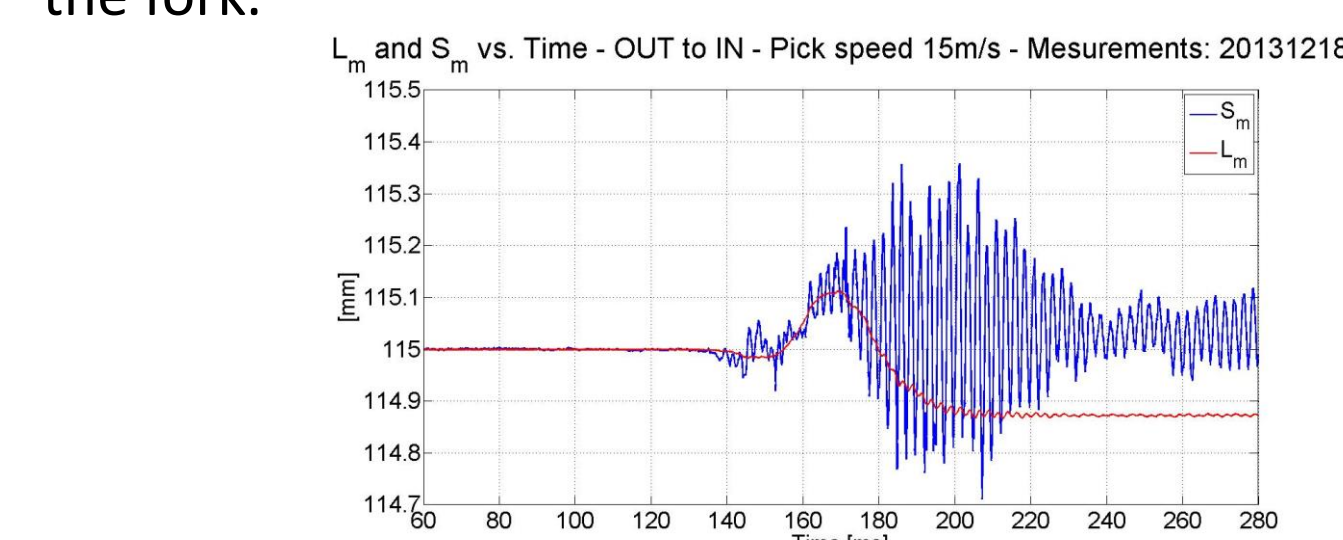


FFT performed in the signal of G1 and G5 show two peak frequencies which correspond to the first and second natural modes of the fork (~150 Hz and ~400 Hz respectively).

Wire elongation

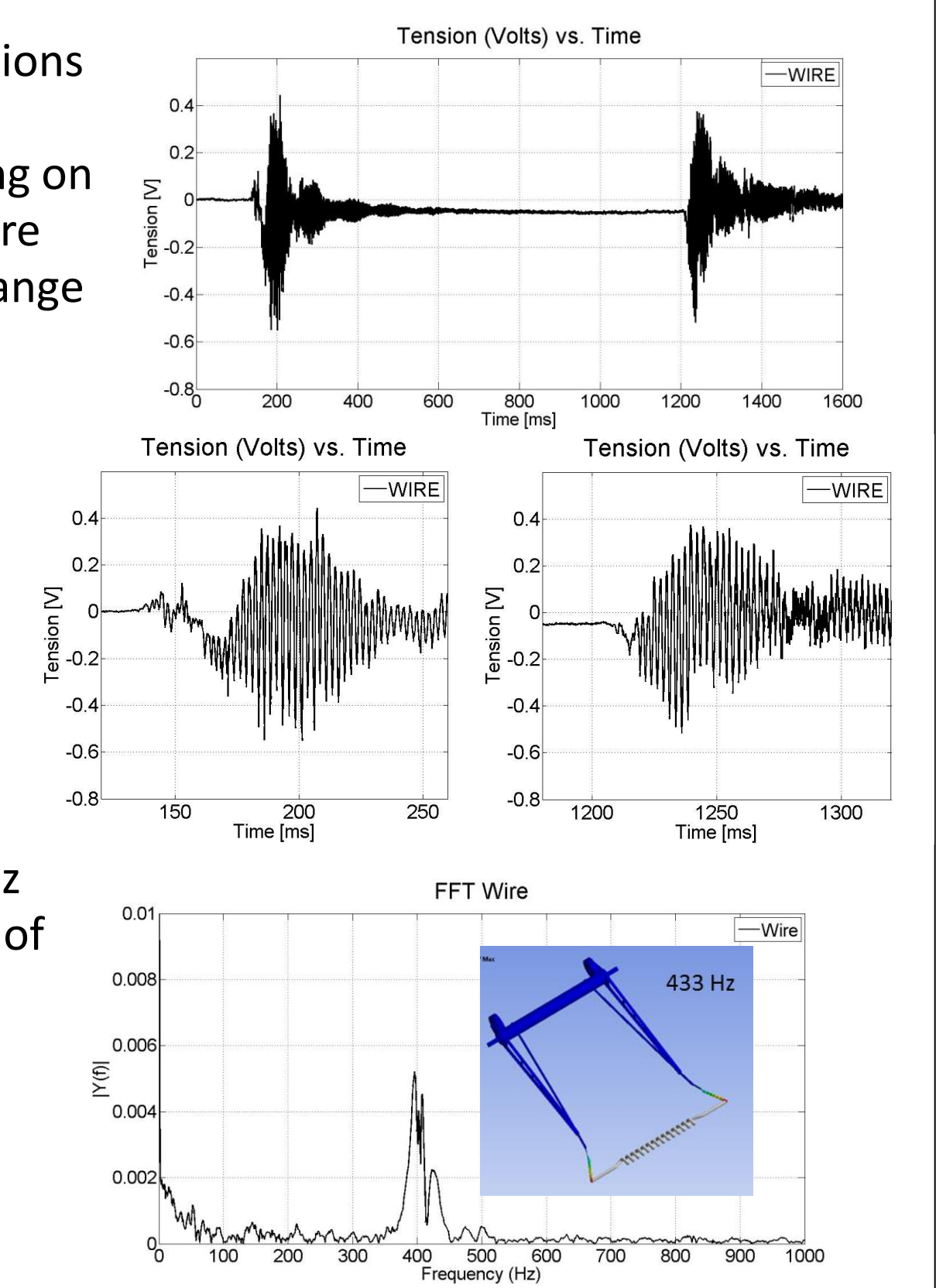


Longitudinal deflections of the fork tips and motion forcers acting on the wire provoke wire elongations that change the wire resistance.



The same trend of the longitudinal deflection (Lm) and wire elongation (Sm) is observed applying experimental factors to G1, G5 and the wire signals.

Wire elongation



FFT performed on the wire signal shows only the second mode (~400 Hz) as the first mode (~150 Hz) does not provoke elongations on the wire.